DEVELOPMENT OF A 2-SEGMENT SPINAL FRACTURE FIXATION ROD TO MEASURE FORCES AND MOMENTS IN VIVO

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Introduction

Little information exists with regards to the loads acting on spinal rods during fracture stabilization and healing. Spinal trauma of the thoracolumbar junction represents 60-65% of thoracolumbar spine fractures [1]. Lumbar disc measurements were carried out first by Nachemson [2] and then by Wilke [3]. Forces carried by modified spinal fixators have been measured by Rohlmann et al [4]. Our current work is directed towards instrumenting a standard geometry spinal rod and stiffness used for fracture healing as seen in figure 1. Strain gauges housed internally measure the 6 dof of loading acting at the centre of the rod. This will enable the load sharing between rod and spine to be assessed and indicate the optimal time for removal of the rod [5].

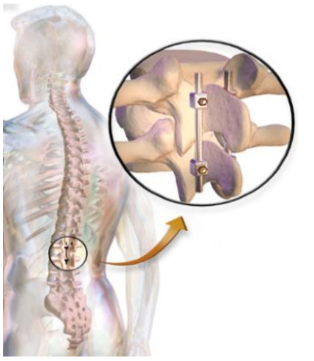

Figure 1: Example of spinal implants used to stabilise the spine.

Method

Grade 9 Ti-3Al-2.5V titanium tubes of 6.35mm outer diameter were instrumented internally with 9 strain gauges. The load bearing solid outer tube of wall thickness 0.7mm and a single inner sleeve of 160deg arc with a length of 60mm were manufactured. Strain gauges and electronics are pre mounted. Implant instrumentation is being evaluated for resolution, power, and speed. Strains will be amplified, digitized, telemetered, and powered using inductive coupling between an implanted coil contained at one end of the rod and an external coil [6]. The model was finite element analysed using COMSOL^{TM} to validate the choice of strain measurement sites for efficacy of load sensitivity and selectivity. The construct both with electronics and without were then mechanically tested using a Wohler rod rotating machine, thus determining whether the instrument will be able to withstand cyclic fatigue loading conditions.

Results

The proposed construct was designed on COMSOL, appropriate boundary conditions and material settings were applied. 3 forces and 3 moments were applied separately. Machining grooves present in manufactured single sleeves dictated the 5 axial levels chosen, strains corresponding to the outer surface of tube and inner sleeve were tabulated out. Strains were analysed, sinusoidal profiles and their phase relationships were compared. Sensitivities and correlations were checked against various angle combinations and gauge locations were chosen as seen in figure 2.

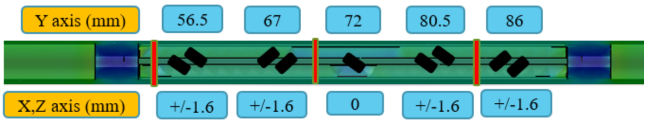

Figure 2: Gauge locations and their positioning in the X, Y and Z axis within the grooves on the inner sleeve to be instrumented.

Errors and peak sensitivities varied with the angle of the rotated gauges. Gauges at 0 degrees gave the best ideal sensitivity for Fy,Mx,Mz and 45 degrees gave the best sensitivity for My,Fx,Fz. Correlation coefficients between the degrees of freedom were high but expected due to the regular structure of the implant. Ability of the combined chosen gauge sites to uniquely determine the 6 degrees of freedom applied were proven. 9 strain gauge channels were made available to allow room for errors during gauge placement. 5 levels were used for better discrimination and more selectivity, a combination of circumferential and rotational angles. To theoretically facilitate 'infinite' life, gauges will use a power coil to be inductively powered, and an antenna to transmit data. This aspect of electronics, powering and telemetering data out is subcontracted and currently on going. 8 outer tubes 150 mm length and 6 welded tubes of the same length encapsulating the inner sleeves were manufactured and polished to run further experimental tests. The fatigue test was set up in line with the titanium grade 9 used. Strain/bending moment of 627/ustr/Nm was calculated, corresponding to a fatigue failure bending moment of 4.5Nm. 1 million cycles corresponding to practical cyclic stresses of the implant are currently under going testing.

Future Work

Further testing in practice using calibration loading in a biomechanical study prior to use in vivo.

References

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